
# Energy consumption characterization as an input to building management and performance benchmarking – a case study

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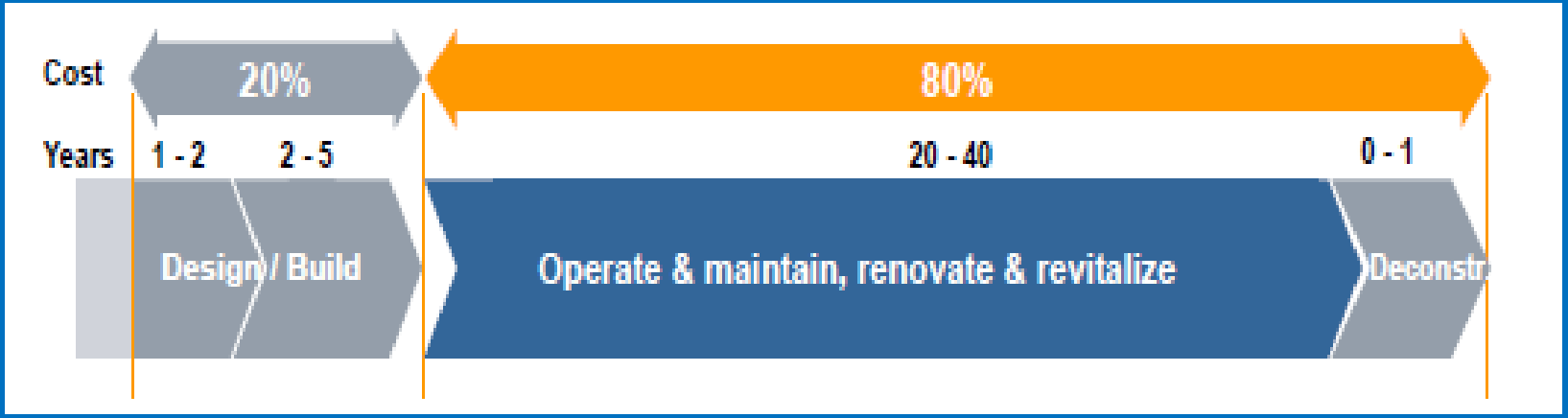
# Building energy performance benchmarking

- The starting point for increasing energy efficiency against which each subsequent target is defined;
- Allows comparing a building to itself or to a sample of other similar buildings;
- Assess effectiveness of current operations, policies and practices;
- Identifies opportunities for cost reduction and increased energy efficiency;
- Easy to use and understand.

# Building energy benchmarking

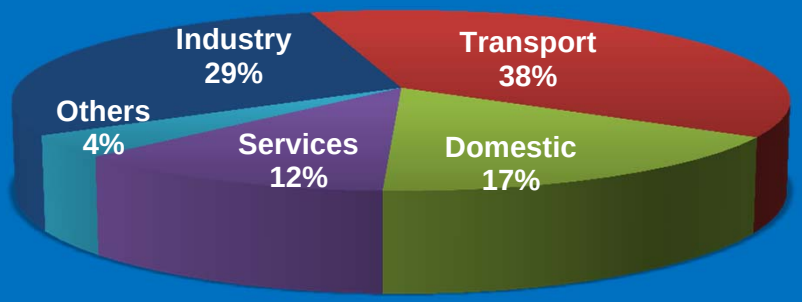
- The need…




**About 80% of a building´s lifecycle costs are associated to its operation stage!**

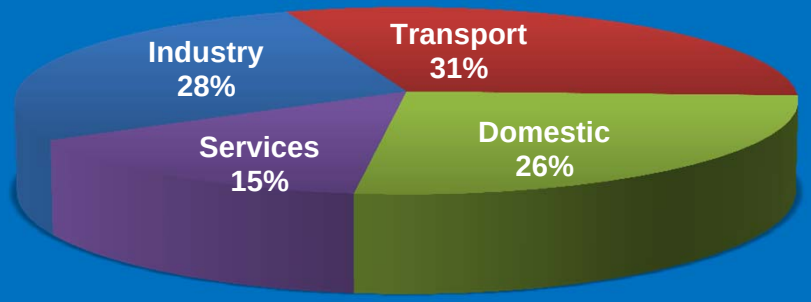
# Energy outlook

## Portugal




**Buildings:**
**29% of final energy**

## EU - 25

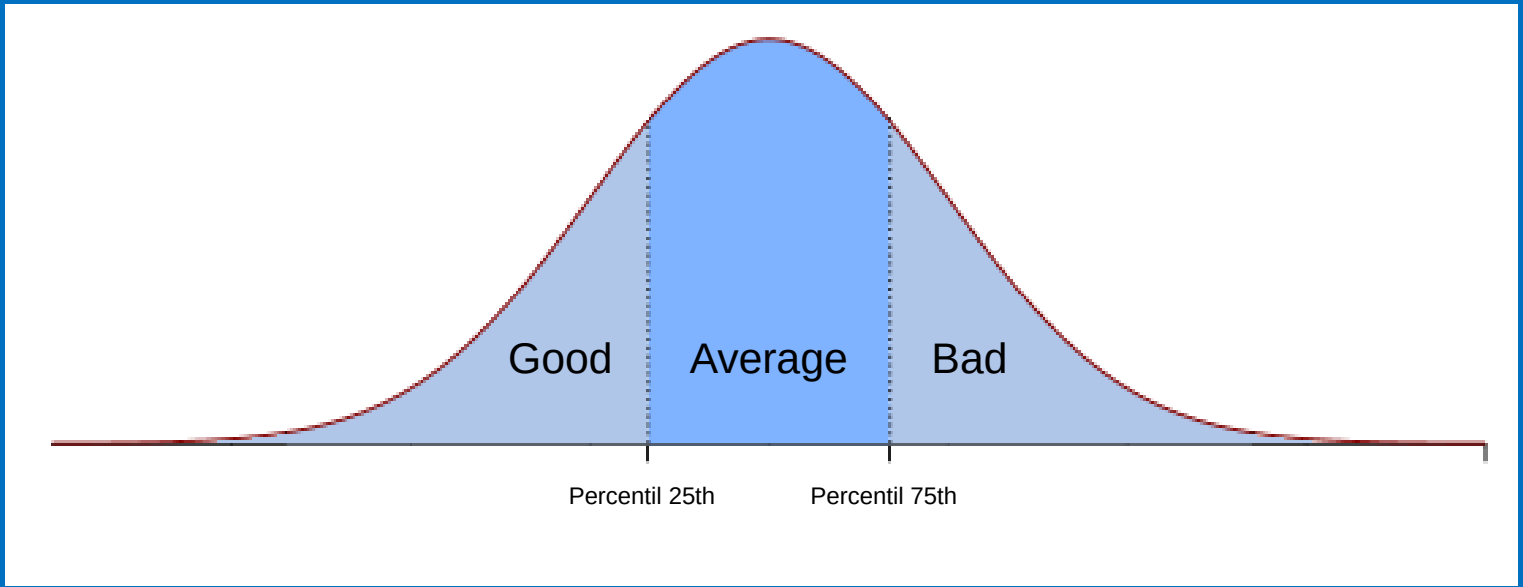



**Buildings:**
**41% of final energy**

# Methodological approach

- Individual building energy audit (data collection);
- Classification of buildings into typologies (according to main end-use activity developed);
- Calculation of energy efficiency indicators in kgoe/$m^2$/year and kgoe/meal and environmental indicator in kg$CO_2$/kgoe;
- Sensivity analysis of correlations;
- Ranking buildings into categories: Good, Average and Bad.

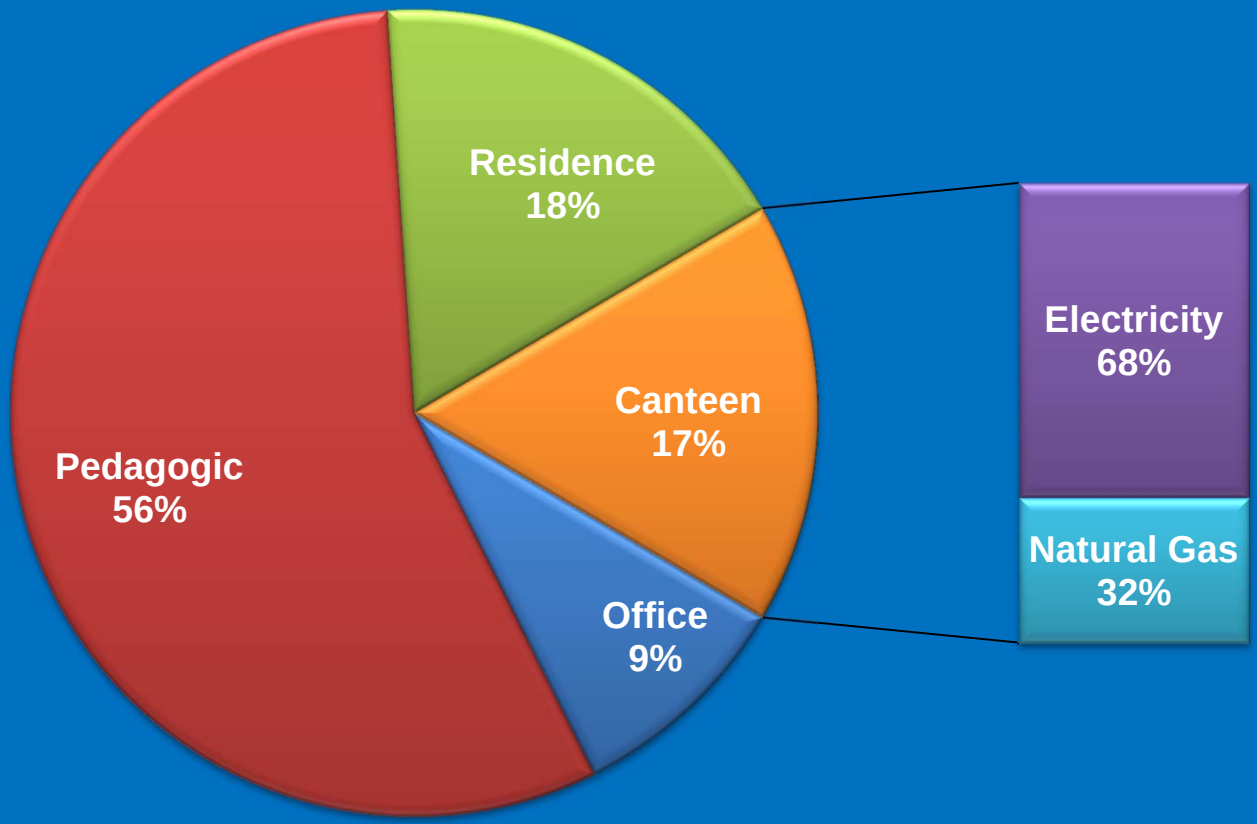
# The ranking system



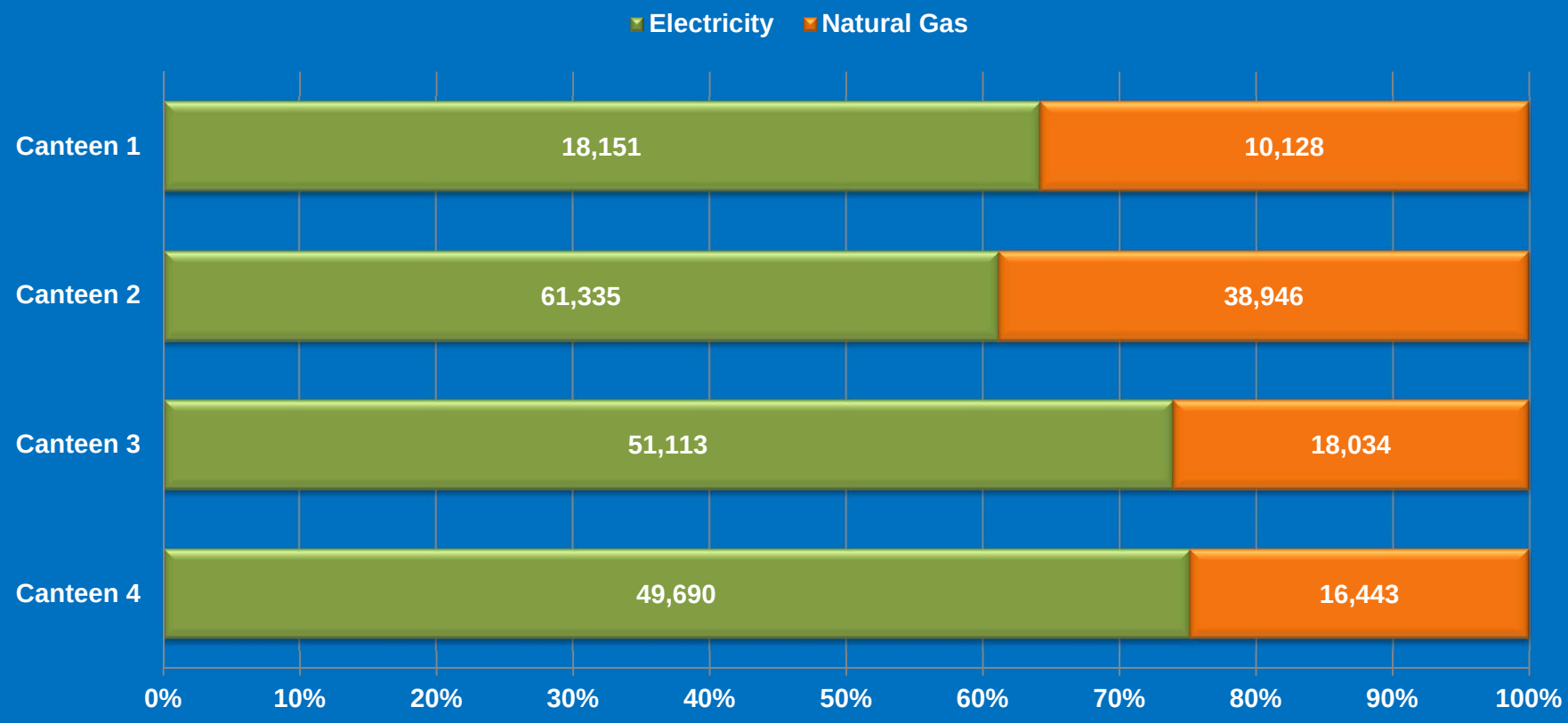
# Buildings of Polytechnic Institute of Leiria, Portugal

| Building | Typology | Net floor area [$m^2$] | Energy consumption [kgoe] | GHG emissions [$kgCO_2e$] |
|---|---|---|---|---|
| C1_Canteen_1 | Canteen | 842 | 28.279 | 56.598 |
| C2_Canteen_2 | | 2.336 | 100.281 | 203.924 |
| C2_Canteen_3 | | 1.484 | 69.146 | 131.234 |
| C3_Canteen_4 | | 1.193 | 66.133 | 124.659 |
| C2_Library | Library | 3.333 | 162.246 | 277.277 |
| Administration_building | Office | 2.616 | 47.813 | 77.491 |
| C1_Building_C | | 591 | 3.953 | 6.407 |
| C2_Building_B | | 3.135 | 54.221 | 102.046 |
| C5_Building_1 | | 2.045 | 37.280 | 66.687 |
| C1_Building_A | Pedagogic | 4.358 | 76.111 | 123.352 |
| C2_Building_A | | 12.063 | 243.050 | 434.941 |
| C2_Building_D | | 8.851 | 274.184 | 475.605 |
| C2_Building_E | | 507 | 30.378 | 49.233 |
| C2_Health_School | | 4.438 | 122.670 | 198.810 |
| C3_Building 2 | | 2.085 | 12.422 | 20.133 |
| C4_Building_ESTM | | 6.542 | 110.529 | 184.712 |
| C1_Building_B | | 1.385 | 8.797 | 14.257 |
| C2_Building_C | Research | 1.320 | 37.826 | 79.782 |
| Students_Residence_ D | Residence | 1.300 | 33.173 | 78.861 |
| Students_Residence_A | | 1.460 | 41.551 | 86.098 |
| Students_Residence_B | | 1.452 | 38.426 | 90.419 |
| Students_Residence_MAD | | 1.753 | 38.867 | 87.436 |
| Students_Residence_Peniche | | 1.019 | 19.467 | 43.433 |
| Students_Residence_RBP | | 1.990 | 33.755 | 74.161 |
| Students_Residence_ C | | 1.744 | 69.445 | 133.002 |

# Energy breakdown by typology of building



# Canteens – fuel breakdown

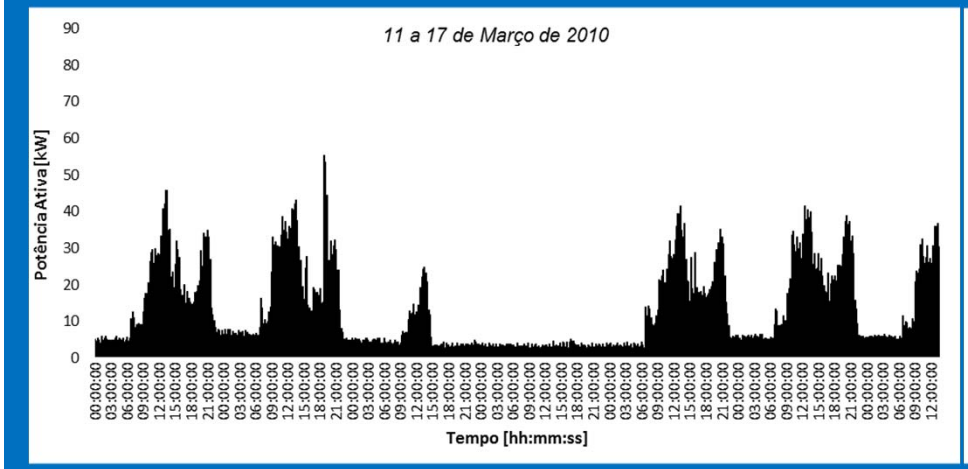


# Canteens – some informations

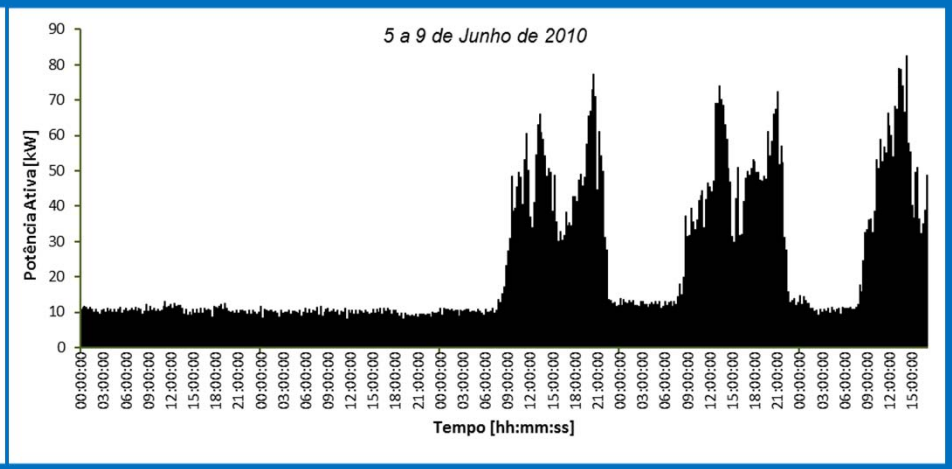
| Building | Year of construction | Net floor area [$m^2$] | Number of meals | Energy consumption [kgoe] | GHG emissions [$kgCO_2e$] |
|---|---|---|---|---|---|
| Canteen 1 | 2002 | 842 | 89.972 | 28.279 | 56.598 |
| Canteen 2 | 1997 | 2.336 | 128.008 | 100.281 | 203.924 |
| Canteen 3 | 2006 | 1.484 | 134.711 | 69.146 | 131.234 |
| Canteen 4 | 2006 | 1.193 | 57.253 | 66.133 | 124.659 |

# Electricity – load profiles

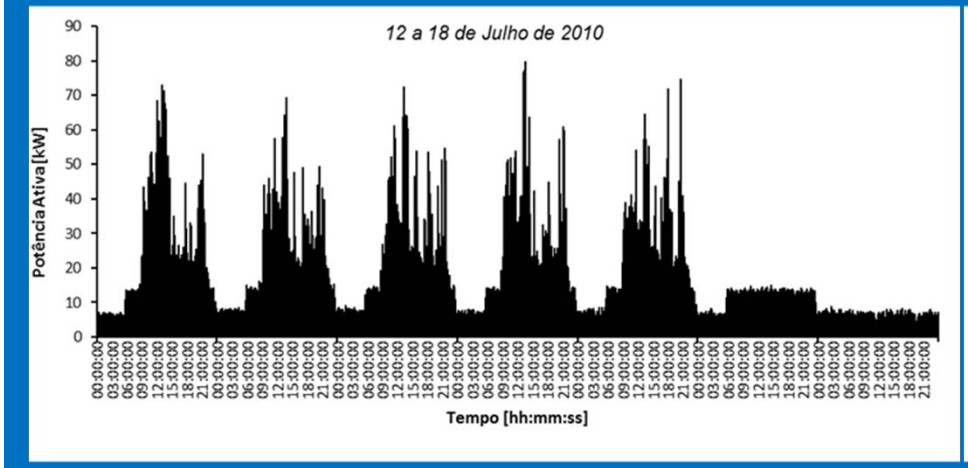
- Canteen 1



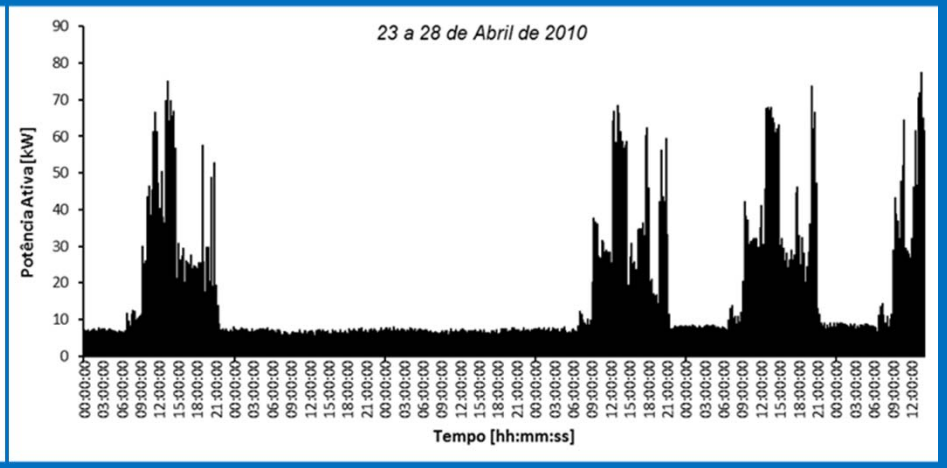

- Canteen 2



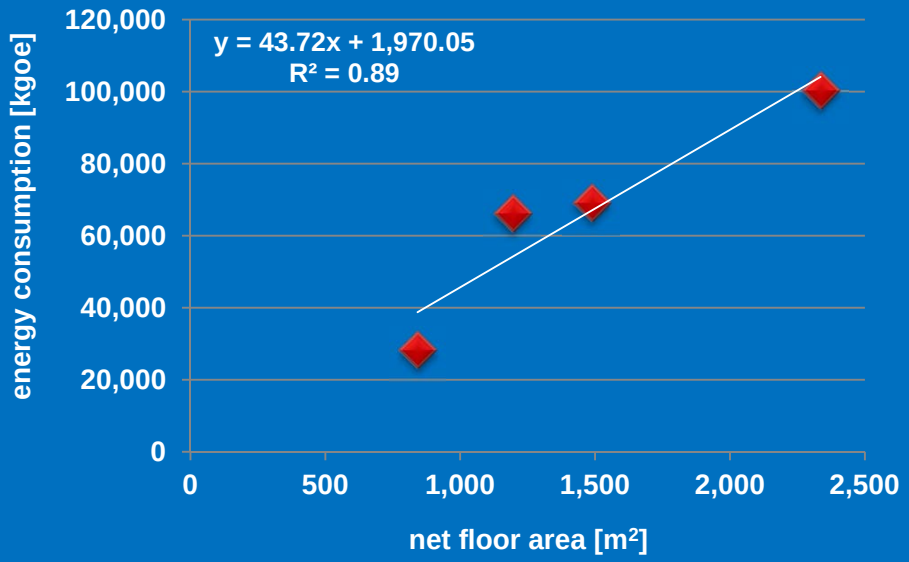

- Canteen 3

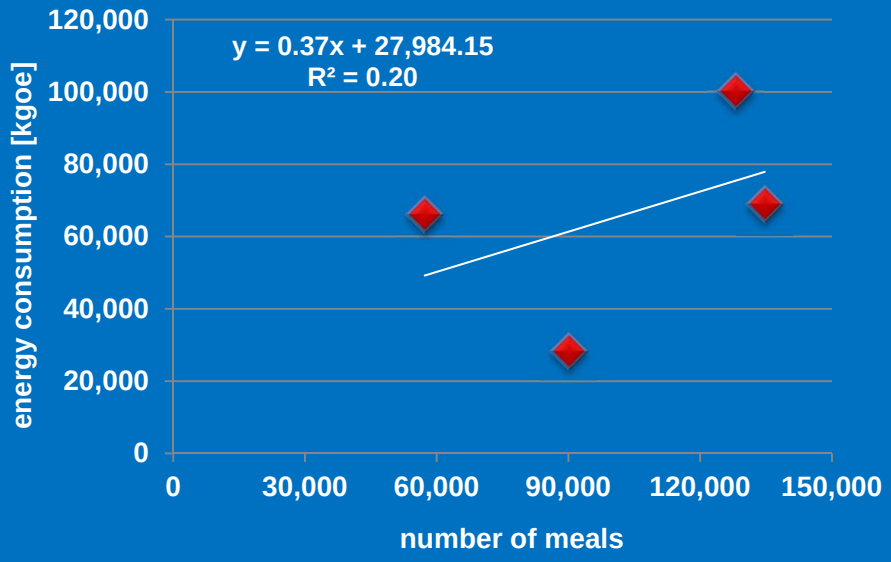



- Canteen 4



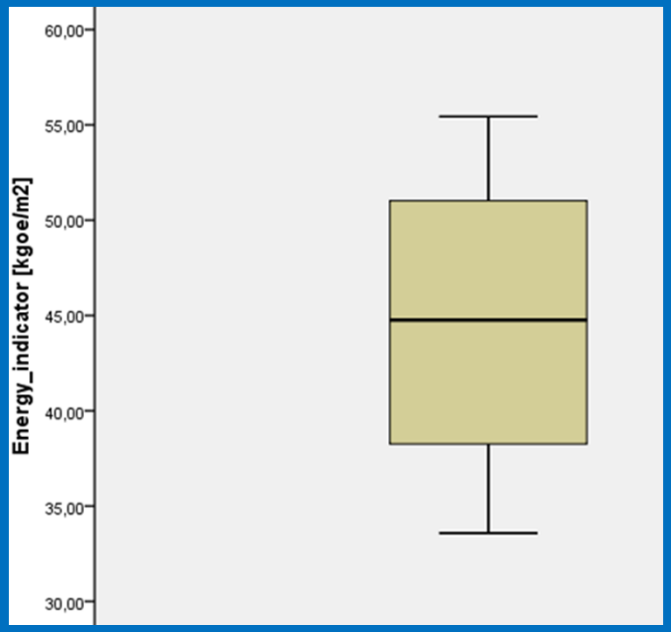
# Variation of primary energy with number of meals and net floor area

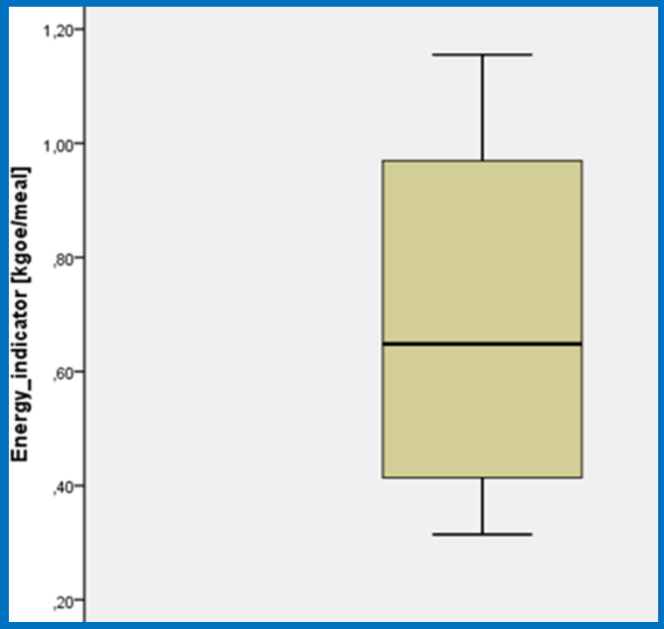



| Building | Energy indicator [kgoe/meal] | Energy indicator [kgoe/m$^2$] | GHG Indicator [kg$CO_2$e/kgoe] |
|---|---|---|---|
| Canteen 1 | 0,31 | 33,59 | 2,00 |
| Canteen 2 | 0,78 | 42,93 | 2,03 |
| Canteen 3 | 0,51 | 46,59 | 1,90 |
| Canteen 4 | 1,16 | 55,43 | 1,88 |

# Statistical summary – energy indicators



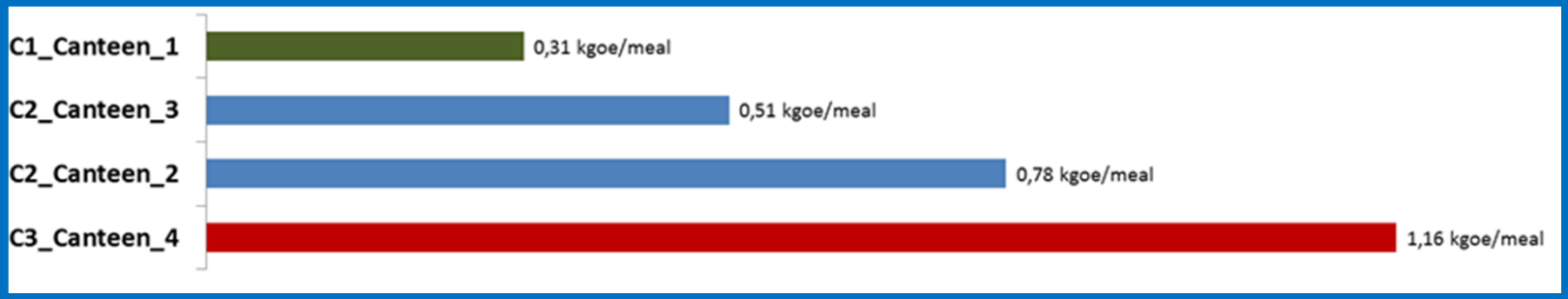




| Energy Indicator | Mean | Std. deviation | Minimum | Percentile 25th | Median | Percentile 75th | Maximum |
|---|---|---|---|---|---|---|---|
| [kgoe/meal] | 0,69 | 0,36 | 0,31 | 0,41 | 0,65 | 0,97 | 1,16 |
| [kgoe/m$^2$] | 44,64 | 9,05 | 33,59 | 38,26 | 44,76 | 51,01 | 55,43 |

# Building ranking

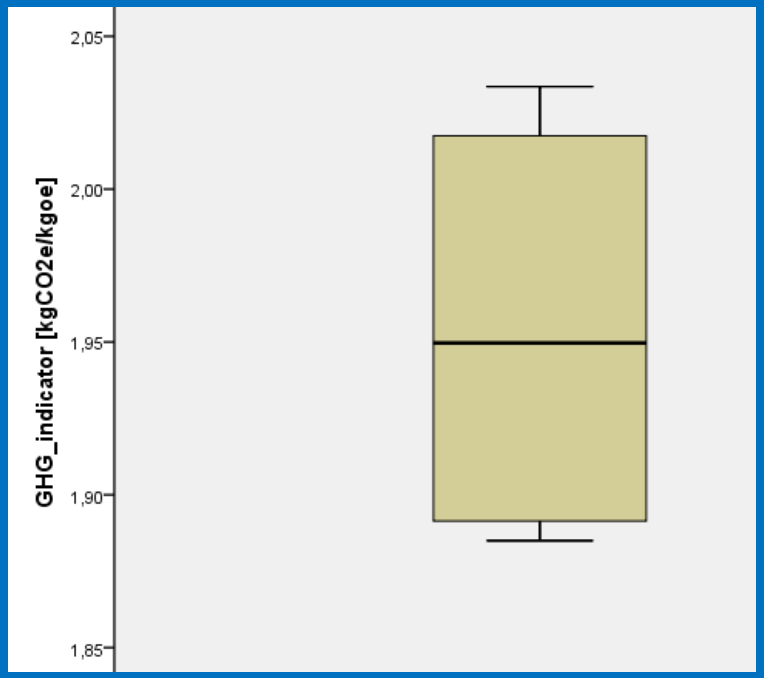
- Buildings ranked by energy indicator [kgoe/m$^2$]:


- Buildings ranked by energy indicator [kgoe/meal]:




**Note:** Green bars correspond to buildings considered Good, blue bars to Average and red bars to Bad.

# Statistical summary – GHG indicator




| GHG Indicator | Mean | Std. deviation | Minimum | Percentile 25th | Median | Percentile 75th | Maximum |
|---|---|---|---|---|---|---|---|
| [kgoe/kg$CO_2$e] | 1,95 | 0,07 | 1,88 | 1,89 | 1,95 | 2,02 | 2,03 |

# Building ranking

- Buildings ranked by GHGE indicator [kgoe/kg$CO_2$e]:


**Note:** Green bars correspond to buildings considered Good, blue bars to Average and red bars to Bad.

# Conclusions

- The definition of an energy efficiency indicator is a technical challenge that influences the selection of the appropriated energy policy for each building;
- Energy performance indicators give only a broad indication of building efficiency and therefore must be treated with caution;
- Energy performance indicators can mask underlying problems with individual end uses of energy;
- It should not be assumed that a building with a ‘good’ performance indicator is in fact being operated as efficiently as is possible, or offers no scope for cost-effective savings;

# Conclusions

- Higher education buildings have specific characteristics that differ from other buildings, such as longer opening hours, resulting in longer occupancy when compared with other services buildings;
- The results are useful to identify if the buildings energy performance is poor, average or good comparing to the same type of buildings and to provide a useful first indicator for support decisions on the implementation of actions that improve buildings energy efficiency;

# Conclusions

- The results allow further knowledge on the overall energy consumptions of a set of buildings, which in term may aid the decision-making process, for instance when evaluating different investment options, or when ordering a list of priority of interventions according to each actual effectiveness and pertinence;
- Similar studies should be performed with a larger number of buildings, from different typologies, in different sectors of the economy;

# Conclusions

- Energy efficiency in buildings operation only can be achieved through a continuous energy monitoring and management system;
- Energy benchmarking is also useful to give the measure of the progress over time for energy management programs.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